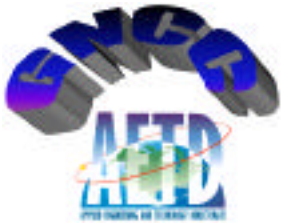

STScI NGST Libration Point Introduction

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History, Definitions, & Modeling

History

Euler

- Defined three body problem in work on lunar motion.
- Proved existence of co-linear points

Lagrange

- Development of equilibrium points

Poincare

- Stability of motion and use of potential functions
- First to recognize the need for a qualitative approach to three body problem which is unsolvable in closed form

Jacobi

- One exact integral of three body system

Definitions & Modeling

- Easiest to model the system as the Circular Restricted Three Body Problem (CRTBP) where $m_1 >> m_2 >> m_3$
  - m_1 - primary, m_2 - secondary, m_3 - body of interest
  - motion of Earth about Sun is circular
  - motion of m_3 is in plane of m_1 & m_2
- CRTBP can be solved exactly
- Unfortunately, unmodeled forces (solar radiation pressure, other gravitational bodies - Jupiter, etc.) and physical reality (non-circular motion or EM system about sun) cause perturbations

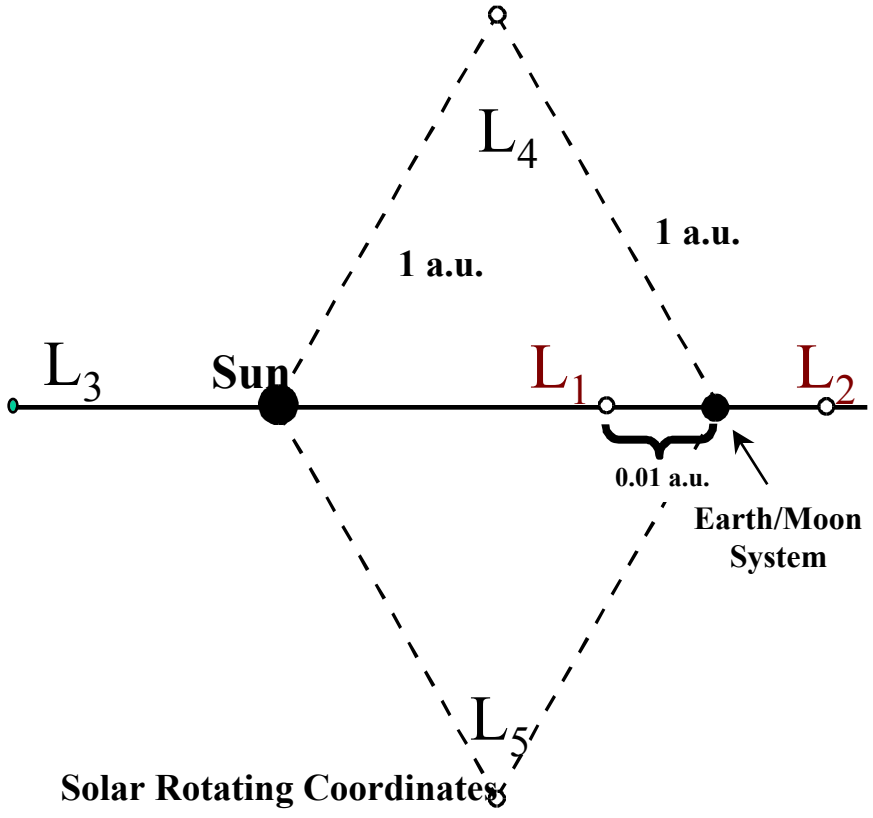
The Libration Points

What Are They??

- Equilibrium or libration points represent singularities in the equations of motion where velocity and acceleration components are zero and the forces are balanced
- Viewed in the rotating frame: centrifugal (Coriolis-Type) force balances with gravitational forces of the two primaries
- Libration points are in plane with no Z component
- Our system of interest involves the Sun (m_1), the Earth-Moon system (m_2) and the spacecraft m_3

Where Are They?

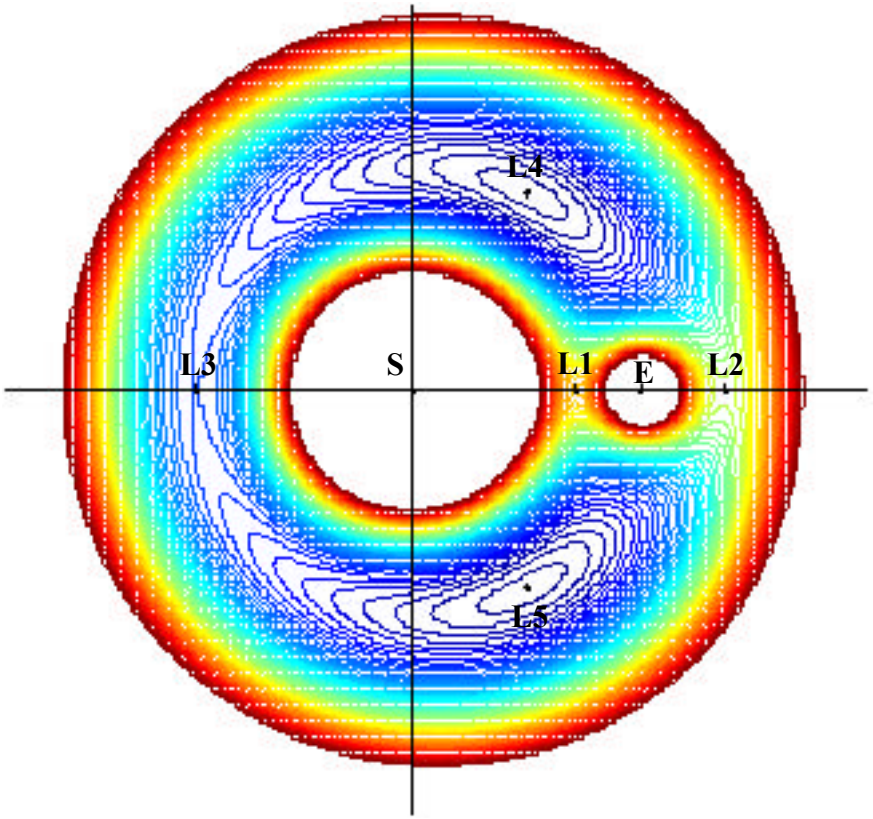
- Collinear Points: L_1, L_2, L_3 (unstable)
- Triangular Points: L_4, L_5 (stable)



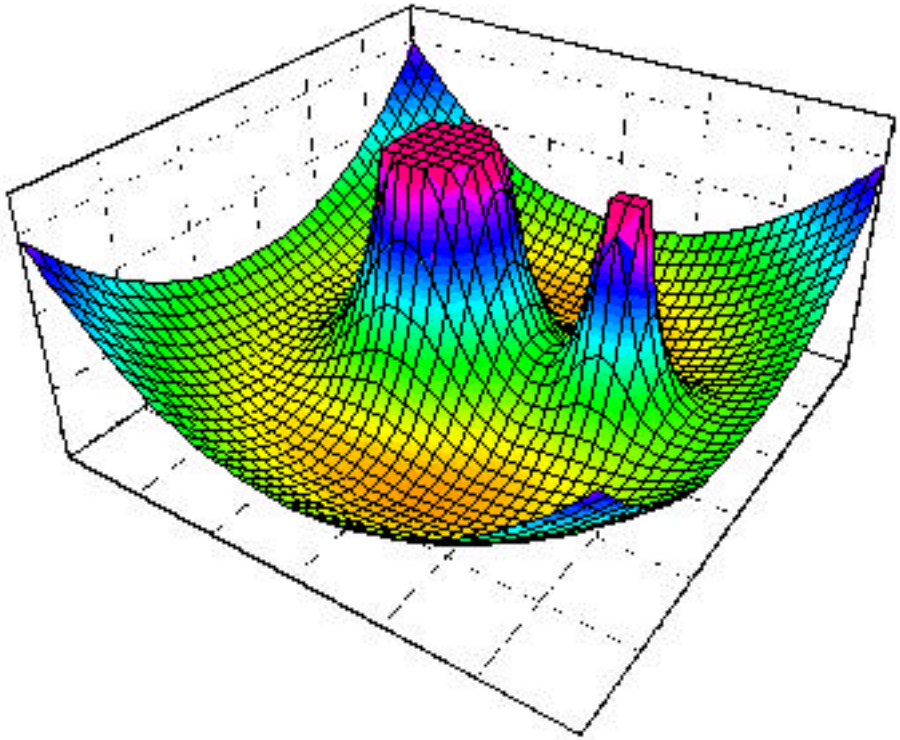
Potential for Planar CRTBP

$$V^2 = x^2+y^2 + [2(1-\mu)/r_1]+ [2\mu/r_2]-C$$

2-D View (Ecliptic Projection)



3-D View of Potential (fixed C)



Motion About the Libration Points

- Periodic solutions can be found for motion about the collinear libration points in the CRTBP
  - $x = K A_Y \sin(\omega_{XY} t + \varphi_{XY})$
  - $y = A_Y \cos(\omega_{XY} t + \varphi_{XY})$
  - $z = A_Z \sin(\omega_Z t + \varphi_Z)$
- Period of motion about libration points is 180 days
- There are two types of motion about libration points
  - Lissajous orbits
    - $\omega_{XY} \neq \omega_Z$
    - As a result, the orbit oscillates about the y-axis such that the projection along the sun-line seems to open and close
    - Because of this motion, constraints on a solar exclusion zone or eclipse region may be required
  - Halo orbits
    - Special solution of the libration point orbit where $\omega_{XY} = \omega_Z$ and $A_Y > 655{,}000$ km

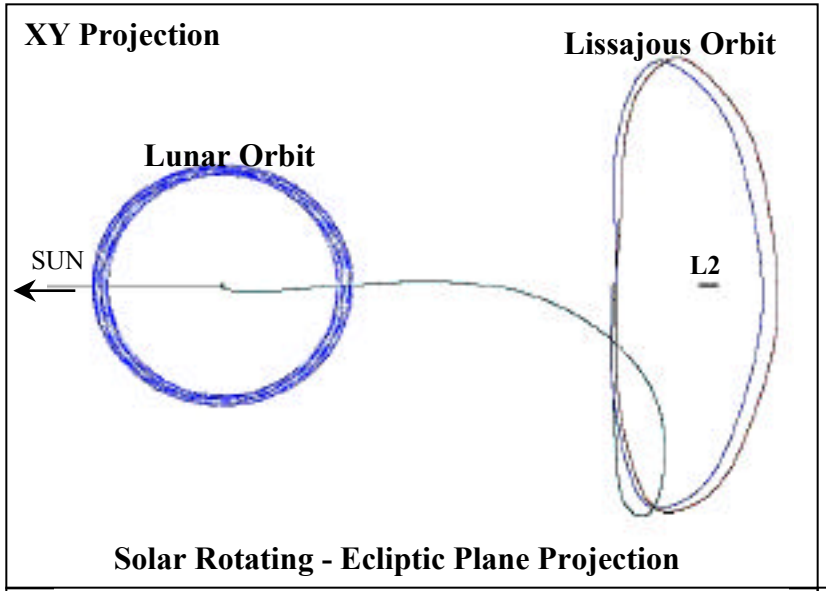
Lissajous Patterns (MAP)

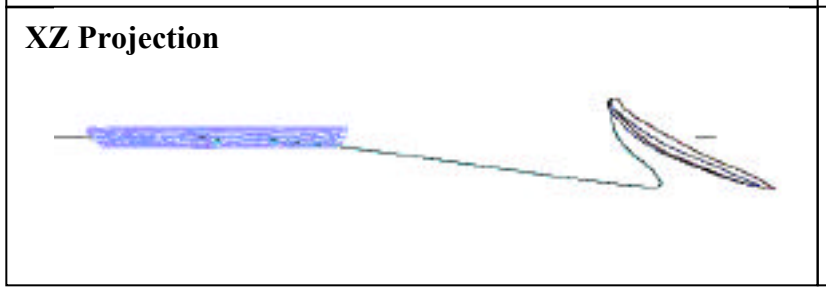
14 Year Evolution

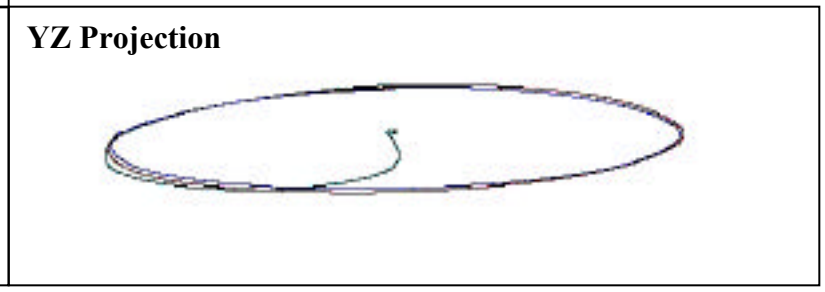
6 Year Evolution

Getting to L2

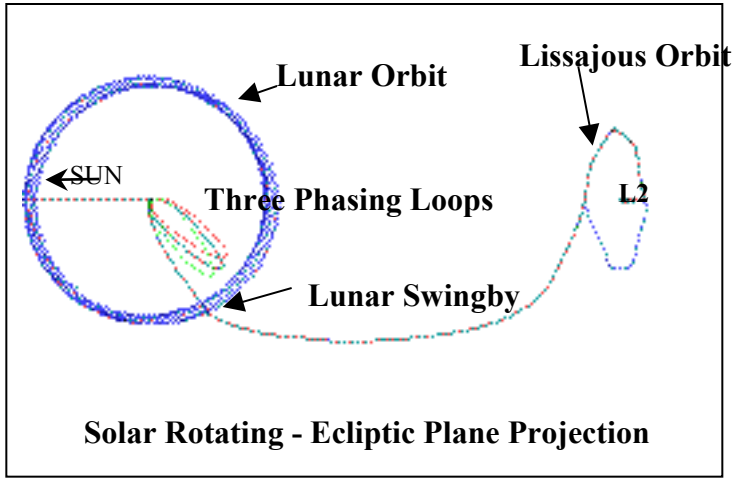
Direct Injection





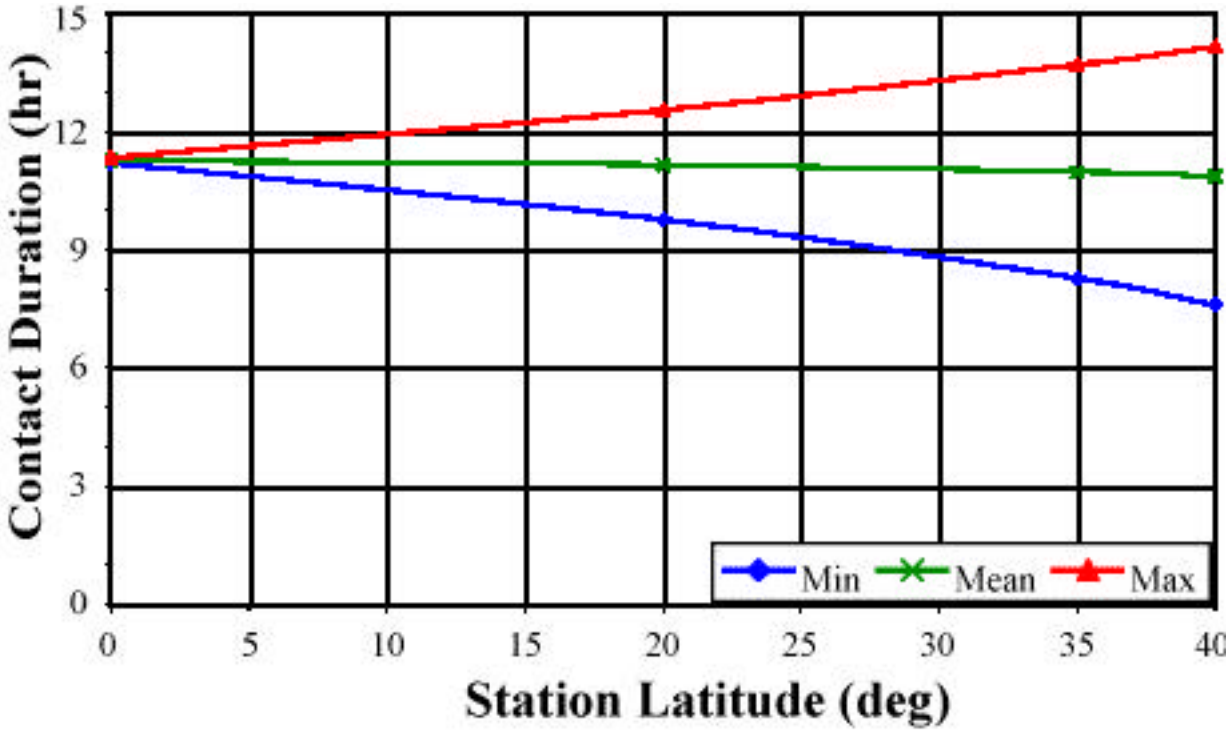


Lunar Swingby



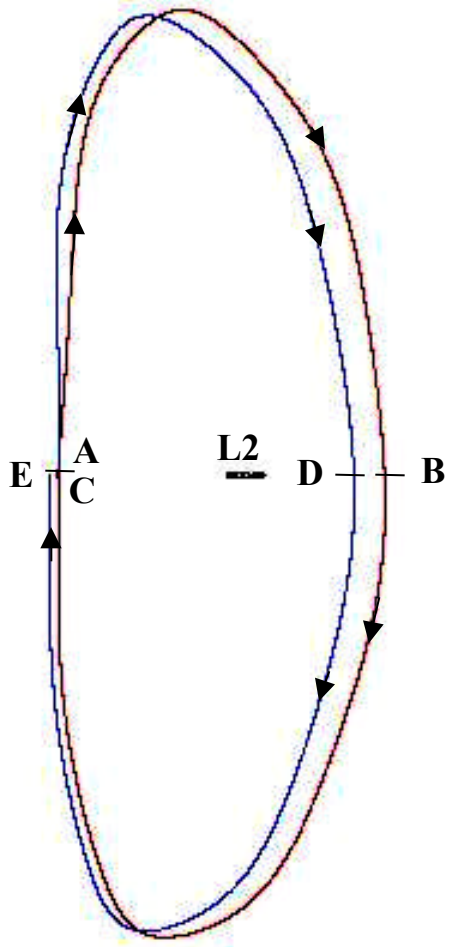
Contacting NGST

- Fortunately, ground contact time to NGST is abundant out at L2
- Coverage ranges from 8 to 14 hours a day depending on the station latitude (assuming a 5° minimum elevation at the station)
- Ranges to NGST are
  - Minimum: 1.22 x 10^6 km
  - Average: 1.53 x 10^6 km
  - Maximum:1.73 x 10^6 km
- For reference, DSN latitudes at Goldstone, Canberra, and Madrid are 35°, -35°, & 40°, respectively



Stationkeeping at L2

- Because of the instabilities of the Lagrangian points, stationkeeping is required to maintain an orbit about L2 for an extended period of time
- At it's simplest, a stationkeeping maneuver is performed at an XZ-plane crossing to provide for a complete revolution about L2 (motion at right is from A☞B☞C☞D☞E)
- For example:
  - a maneuver is performed at point A to ensure a one period revolution to point C
  - then a maneuver is performed at point B to ensure a one period revolution to point D
  - etc.
- Typical stationkeeping costs are anywhere from 2 - 4 m/s per year (depending on the requirements)



NGST Wrinkles to Stationkeeping

- The large sun-shade on NGST (≥ 200 m^2?) provides a continuous perturbation acceleration in the +X direction (away from the Sun) due to solar radiation pressure
- Furthermore, it's now being studied how frequently maneuvers will be needed for momentum unloading
  - these maneuvers will always be in the +X direction (no thrusters allowed on anti-Sun side of shade)
- As a result inventive methods may be needed to assist with stationkeeping and momentum management
  - alternate NGST viewing to minimize momentum buildup
  - use solar shade as 'sail' to supplement stationkeeping options
  - design gimballed solar shade to enable solar 'sailing'

References

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- Szebehely, V., Theory of Orbits: The Restricted Problem of Three Bodies, Academic Press, New York, 1967